NASA TECHNICAL TRANSLATION

NASA TT F-251

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# THE RELATIONSHIP BETWEEN PHOTOSPHERIC AND CHROMOSPHERIC PROCESSES IN THE ACTIVE REGION DURING FLARES

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From *Solnechnyye Dannyye,* No. 4, 1963.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • SEPTEMBER 1965

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Translation of "O svyazi fotosfernykh i khromosfernykh protsessov v aktivnoy oblasti vo vremya vspyshek." Solnechnyye Dannyye, No. 4, pp. 77-81, 1963.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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THE RELATIONSHIP BETWEEN PHOTOSPHERIC AND CHROMOSPHERIC PROCESSES IN THE ACTIVE REGION DURING FLARES /77

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ABSTRACT

Sunspot activity and solar flares accompanied by particle emissions along radial lines have been carefully studied using motion pictures and photoheliograms. A superposition of the two has allowed investigation of detailed sunspot distributions. The data obtained have been used to calculate the total number of atoms in the active region of the chromosphere and in the whole solar corona. When these values are compared with the total number of atoms, the source of particle emission and strong flares is found to be in the photosphere. Furthermore, magnetograph records indicate an increase in radial velocity in photospheric levels during solar flares. It is shown that among the increased mass of ascending substances in the photosphere, sunspot displacement, particle surges in the chromosphere above the sunspots during solar flares, and the solar flares themselves, there exists a very intimate relationship. All these phenomena are then assumed to be due to a single primary process occurring, in all probability, within or immediately below the photosphere.

Solar flares are generally accompanied by emissions which in rays of line $H_\alpha$ on the disk are visible in absorption.

Films of solar flares were used to determine the time distribution of the appearance of these emissions in connection with the development of flares in $H_\alpha$. On the basis of these films, brilliance curves were constructed for every cluster of 30 large flares; the moments of appearance and the duration of the emissions were also noted. Figure 1 illustrates this procedure as applied to the flare of July 14, 1959, which measured 3+. Under the brilliance curves in Figure 1, the beginning and conclusion of emissions are shown on the time scale, separately for each spot. The number appearing at the left near each series of emissions indicates the number of the spot in the sketch drawn in the illustration; the broken line shows the interval during which the spot was partially or wholly covered with luminous material.

On the basis of the graphs obtained, it was possible to establish that emissions were present during the entire duration of a flare. The appearance of an emission, or a group of emissions, was always accompanied by increased brilliance in the $H_\alpha$ of the cluster of flares in

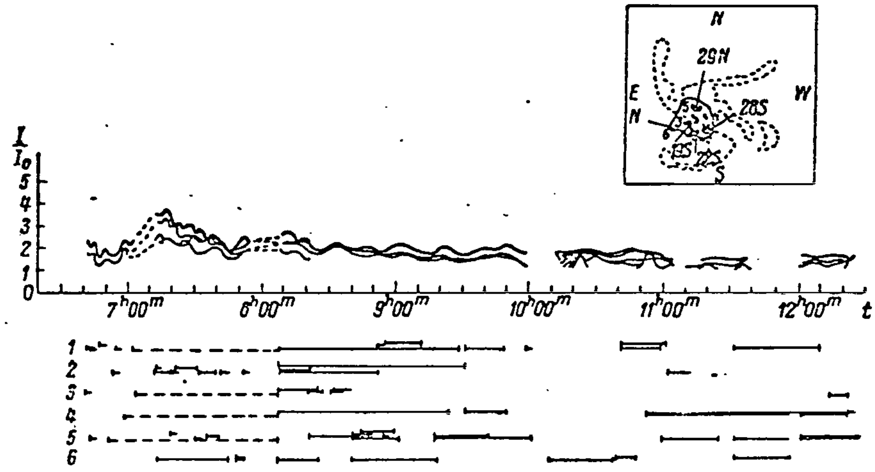



Figure 1

question, or else by the rise of a new cluster. During a flare of 3 or 3+ intensity, the number of emissions may be very large, e.g., in the case of Figure 1, about 50.

The precise point at which emissions appear can be established only for small flares, whose luminous material occupies a large part of the active region. Since on motion picture films only large sunspots are to be seen and their penumbras and small spots are entirely invisible, photoheliograms were used in determining the point of appearance of emissions in connection with sunspots. Figure 2 is an example of a sketch obtained by combining outlines from motion picture films and photoheliograms (for the July 24, 1961 flare). Here the sunspot nuclei are shaded, the penumbra boundaries are indicated with solid lines, the emissions are hatched, and clusters of flares are marked with crosses. Combining the outlines made from motion picture films and photoheliograms made it clear that among the 50 large absorption emissions whose point of /78 localization on the films was not a matter of any doubt, there was not a single instance in which an emission made its appearance in the undisturbed areas of the photosphere. All the emissions originated in the penumbras or even in the umbras (nuclei) of sunspots (see Figure 2). Therefore, in contrast to the opinion accepted until now, sunspots are quite active formations.

For limb flares we obtained the relative distribution of the number of flares with respect to the angle of inclination to the vertical to the limb; this distribution agrees well with the distribution of lines of force in a sunspot as established by Bumba (Ref. 1), if we assume that emissions move along the lines of force of a magnetic field.

According to observational data, the velocities of absorption emissions in projection on the solar disk reach 100 km/sec, while their density is about $10^{12}$ cm$^{-3}$. The average time during which an increase in the length of an emission is observed, is $t \approx 3 \cdot 10^{2}$ sec. Taking these values, and assuming that the number of emissions for a large flare is $k = 30$, we can estimate the number of atoms $N_e$ removed by emissions during the life of the flare. This number amounts to approximately $2 \cdot 10^{41}$ in the case of an emission cross section of $S = 2 \cdot 10^{18}$ cm$^2$.

In very strong flares almost the entire active region (approximately $4 \cdot 10^{19}$ cm$^2$) is occupied by luminous material. The flares extend to an altitude of $h \approx 5 \cdot 10^{8}$ cm and have a density of $10^{13}$-$10^{14}$ cm$^{-3}$. Hence, the total number of atoms involved in a large flare may be $N_f \approx 10^{42}$.

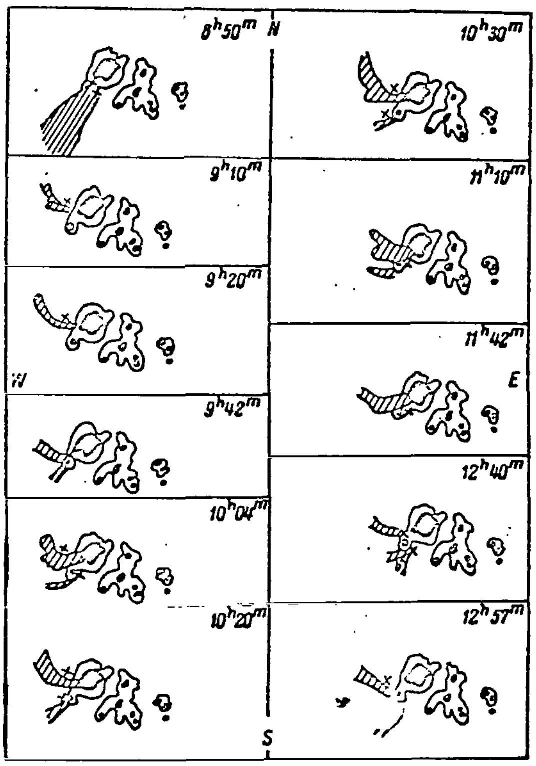



Figure 2

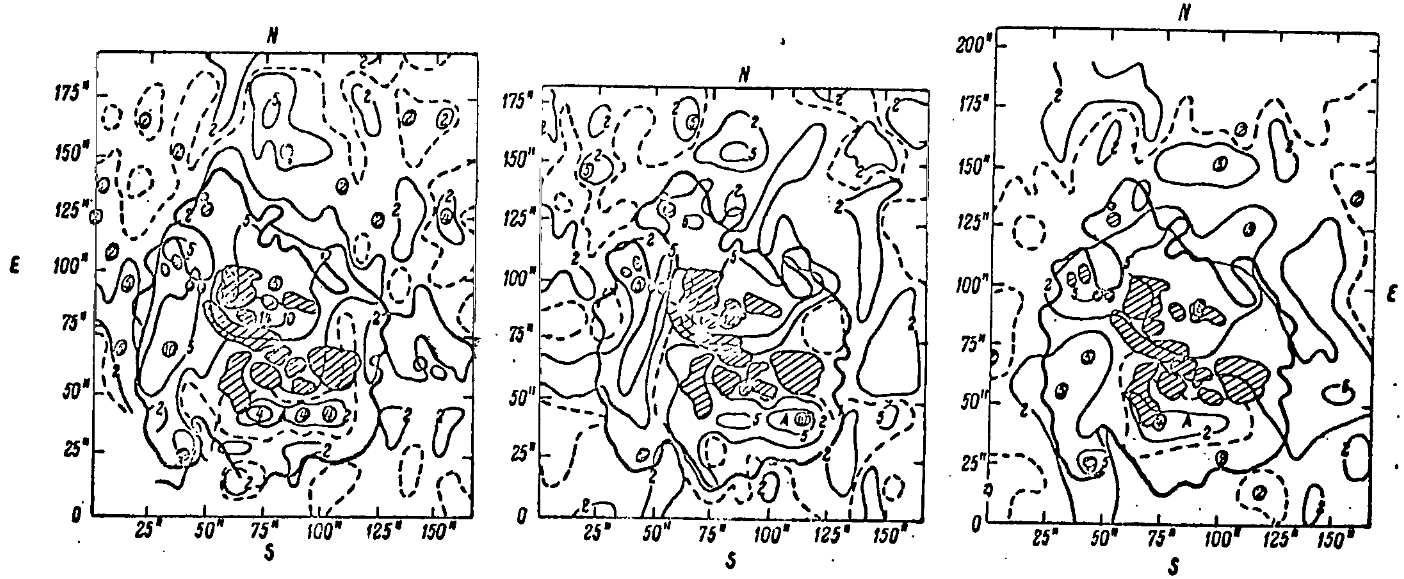
In order to visualize the immensity of this number, one may estimate the number of atoms in the active region of the chromosphere, in the entire chromosphere, and in the entire corona. The figures prove to be as follows: $N_a \approx 5 \cdot 10^{39}$ for the active region; $N_{ch} \approx 2.5 \cdot 10^{42}$ for the entire chromosphere, and $N_c \approx 3 \cdot 10^{41}$ for the entire corona. /79

A comparison of these values of the total number of atoms N shows that the basic source from which material enters the region of a strong flare or goes into emissions is, in all probability, the photosphere. In this connection it is quite important to know the character of change in the field of radial velocities during flares on the level of the photosphere.

From recordings on the magnetograph of The Crimean Astrophysical Observatory it has been established that during solar flares there is an increase in radial velocities at the photospheric level, indicating the rise of gas. Bumba (Ref. 2) and Vasil'yeva (Ref. 3) have also observed an increase in radial velocities during flares. Figure 3 illustrates maps of the field of radial velocities at the photospheric level during the July 14, 1959 flare of intensity 3+. On all these maps the fine solid lines indicate the values of the radial velocities--200 m/sec, 500 m/sec, 1,000 m/sec, and so on. The broken line is the zero line. The region of falling gas is shown in green, the contours of spot penumbras are shown in heavy solid lines, and the region of sunspots is hatched. The maps shown here relate to the following intervals of time (Moscow time): a - 0954 to 1026 hours, b - 1103 to 1140 hours, and c - 1655 to 1740 hours. We should note that the flare in $H_\alpha$ began somewhat before 0642 hours and concluded at 1201 hours.

It is evident from Figure 3 that from 1026 hours a sharp increase in the amount of material at the photospheric level was observed, as well as, according to Ref. 4, a displacement of the "hillocks" of the magnetic field. It was established from the motion picture film (Figure 1) that from approximately this moment there was a significant increase in the number of emissions in the upper layers of the chromosphere above the sunspots.

Thus it appears that there is a very close connection between (1) increase in the mass of rising material in the photosphere, (2) displacement of sunspots, (3) emission of matter in the areas of the chromosphere above sunspots during solar flares, and (4) solar flares themselves. We may therefore assume that all these phenomena are the result of a single primary process which in all probability takes place within the photosphere or the subphotospheric layers. /80




a

b

c

Figure 3

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The Crimean Astrophysical
Observatory

Translated for the National Aeronautics and Space Administration
by John F. Holman and Co. Inc.



NASA-Langley, 1965 F-251

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